Experimentation and Representation in Architecture: analyzing one's own design activity

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Abstract

Architects materialize ideas on physical supports to register their thoughts and to discover new possibilities from hints and suggestions in their own drawings. Uncertainty is inherent to creative processes encouraging the production of different ideas through testing.

This research brings to light that the re-examination of artefacts from new points of view allows for the review and generation of design ideas and decisions, capacitating students to make yet new discoveries from what they have done so far. Tacit knowledge aids specific decisions. Student reports become analytical records of their material registers (sketches, physical and virtual models) making it explicit that which is implicit in those artefacts. This apparently confirms previous studies that suggest that knowledge per se not always triggers or controls decisions in design. Many physical as well as perceptive actions actually lead the initial steps and play a crucial role in the whole course of production. Besides serving as external representations, sketches and models provide visual hints that will be checked later, favouring the upcoming of the unexpected, stimulating creativity. The intent here is to point out how these different means of representation and expression contribute in a peculiar manner to the whole process of discovery and solution to problems in architecture.

The authors propose here a reflection on the process of design and its uncertainties in its initial phase, concentrating on sketches and real models as experimentations. They consider these means not from a graphic and physical register stand point, but in terms of conception and concepts they embody, as records of students thinking and knowledge.

Keywords

Experimentation; Uncertainty; Representation; Design Process; Cognition; Education

Introduction

The Architecture course the authors are engaged in was the second established in Brazil, in 1947. Since the late 1990's the concluding year has evolved to an exclusive one year task of 4 integrated activities – methodology, design, technical research and experimentation – in line with the new ideas ventilated both in the field of architecture and in education as a whole.

Predominantly multidisciplinary and professionalizing it envisages an ethical, culturally solid, diversity minded formation of citizens able to creatively act in a new and ever more challenging world.

The authors, who maintain a parallel line of research on Rapid Prototyping for architectural design, are involved in Activity 4. It deals with testing of architectural hypothesis and possibilities to particular problems students may encounter to concluding their design, reinforcing in them the notion of methodology of design through experimentation, investigation and discovery as instruments of action inherent to the work of the professional architect. The main aim of this long term research is basically twofold: to observe *how* students react and deal with new design situations and, in collaboration with them, to try and establish *what* would the nature and structure of strategies that would allow for them to build their own methodologies for action to solve design problems be. The founding long-term aim is to contribute to a general on-going all-embracing discussion on the structure of the architectural course at hand.

The professional world has come a long way since the Industrial Revolution, when professional formation started to have as its basis a technological programme that aimed at the progress and human prosperity through the logic of science. Knowledge produced in centres of excellence (superior) should be based on irreducible elements of empirical sensorial experience, confirming a previous and objectively established hypothesis (the positivist epistemology of practice). Experimentation was the choice between competing explanatory theories. Professional action would be nothing more than problem solving in nature, from which would be excluded the unpredictable, real phenomena, unexpected situations, the artistic talent (Schön, 1983). After World War II, where these ideas found their peak, in a context of reconstruction, developed societies started to question the capacity of professionals to actually provide solutions to real day-to-day situations for which they had not been trained.

In the midst of a growing debate on the formation of professionals there appeared a notion that knowledge is some kind of informed learning inherent to action. It proposes that students should produce their own knowledge as they do it, through experimentation, aware of the action. Reflection must be a criticism of tacit and sintered knowledge of specialized repetition, allowing for the upsurge of a new meaning to unique and uncertain situations. This means to include in the process issues like complexity, doubt, instability, divergence and diversity, unique character and value conflict – which do no fit into the technical rationality model of a continuum without disturbances.

Teaching and learning in the architectural professional arena is a direct result of social interaction, through active participation and exchange of ideas. It becomes a contribution to students to develop their own research abilities, to search for information to be analyzed and selected and to try and propose something new and contextualized, instead of merely proceeding to the trivial and frequently empty exercises of repetition and memorization. Students should be monitored by someone at that time more experienced, the tutor, who is responsible for the contextualization of learning, making it significant, establishing a relation of reciprocity between the student and the object of study, developing capabilities "(…) *which allow (students) to move*

intelligently from the world of immediate and spontaneous experience to the terrain of abstractions and, from this, to the reorganization of immediate experience" (Castro, 1997).

It means a process of action-reflection-action (Schön, 1983), where experimentation is a central element. Observers perceive something that is unique and pay attention to the phenomenon. They understand the aspects observed organized in a coherent structure that makes sense, a singular meaning, in relation to which they can formulate hypothesis to be tested openly (Schön, 1987). Experimentation is not merely the transmission of ideas or the confirmation of presuppositions. It is not a mere distraction that departs from practice, but a development of it (Schön, 1983).

This investigative spirit induces an important and specific type of learning: to learn how to learn (Rogers, 1978). One appropriate channel to do this may be problematization (Pozo, 1998). Briefly, a problem is a difficulty to be overcome which presents itself to someone without access to a fast and direct way to the solution, demanding reflexive action and decision making capacity even methodologically, as opposed to a simple exercise (Lester, 1983). The problem is the result of a new situation in conscious relationship with a personal repertoire, demanding the strategic use of what is already known (Pozo, 1998), during investigative practice.

Students seek to unravel the problem manipulating and observing it as the process goes. The student who problematizes a new situation, who uses strategies and provides a possible solution to the problem, may get involved in exercises in order to consolidate that new knowledge, but "*as the situations are newer and more open, the solution to problems presents to the student a larger cognitive and motivational demand than the routine exercising of what is known*" (Pozo, 1998).

Means of expression and representation are the instruments of the architect to generate a concept, to develop the idea and to propose its materialization. In order to communicate, students and future architects must position themselves in the other's shoes, to anticipate the built space giving it a particular meaning, through the use of artefacts (computer images, hand drawings and sketches, models, photographs, spoken or written words), which will be revaluated by others. The artefact is an enunciation, and what matters here is to understand it and what is behind it, what is not there. Used with property, the artefact reveals great dominium of architectural language and the construction and expression of meanings. The artefact is the discourse of the author, whose meaning is realized in the context in which it is inscribed. It may be real, but it must allow for the abstraction of the immediate image and the interpretation of its intentional content beyond its simple description. Meaning is not in the artefact itself but in one's mind. This is why it must be open to investigation, testing, modifications, reconstructions.

Therefore, tutors should go beyond the trivial applications of their technical abilities, dialoguing with students in order to help these to move freely from the realm of abstract ideas to that of the real proposition of solutions.

The authors propose here a reflection on the process of design and its uncertainties in its initial phase, concentrating on sketches and real models as experimentations. They consider these means not from a graphic and physical

register stand point, but in terms of conception and concepts they embody, as records of students thinking and knowledge.

Process of Design

The architectural design is a creative gestation process. It defies human capacity to propose solutions to non-anticipated concrete problems. Constant research, testing and discovery are implicit in it, starting with the first photos of the site, comments, notes, sketches, study models including a fixed scenario around the site, virtual constructions, and goes on in the long forward and backward movements of reflective thinking and definition.

When designing, the architect represents and discovers new possibilities from the hints provided by sketches and models themselves. One can perceive, imagine and select multiple interpretations from the artefact produced, activating memory, repertoire and one's capacity to manipulate ideas. The use of cycles of sketching and modeling to explore and generate new ideas appears to be no exception. They are testing instruments and not mere registers of mental images ready in the mind (Herbert, 1992).

Although it is difficult to track the sources of thinking, artefacts may suggest, if partially and limitedly, the successive approximations realized during design. It is possible to follow the route of investigation of the architect of possible ideas taking place in his/her path.

Thinking is inseparable from its means of representation and expression (Herbert, 1992). Artefacts as external representations may aid interpret what has gone on in the mind of the architect. Research taking place in the last decades on the process of design and in the field of cognitive psychology demonstrate that one can map some cognitive operations realized by designers (Akin, 1986; Schön & Wiggins, 1992; Oxman, 1992, 1994 & 1996; Herbert, 1992; Goldschmidt, 1994; Robbins, 1994; Suwa, Purcell & Gero, 1998; Verstijnen, I. M. et. al., 1998; Scrivener, Ball & Tseng, 2000; Goldschmidt, 2004; Bilda, Gero & Purcell, 2006).

Sketches, technical drawings, physical and digital models may serve different cognitive functions in various stages of the design. What is more, each means of representation may contribute or hinder cognitive processes by their own nature. If this is so, then attention to strategies of use and alternation in each phase of the design is fundamental. One system of representation used in an inadequate moment may impede the success of the creative process.

During professional activity, architects gather knowledge and experience rooted in their memories: internal representations manifesting themselves in the cognitive actions in the act of design, as well as external representations like manual drawings, physical and digital models. The role of past experiences on present experience is central for the construction of repertoire in the memory. It may be activated by hints in the artefacts themselves triggering remembrances and associations, allowing for analogies based on similarities with previous experiences.

Most information used by designers is recovered from long term memory (Akin, 1986) and then materialized in representations.

These representations allow for the materialization of their ideas and the improvement of their performance, facilitating comparisons and evaluations. Thus, representations assume the active role in design for they collaborate to turn explicit that which is implicit in the architect's mind.

To learn to design demands the development of many abilities and the production of new knowledge. It means to learn to read one's own graphic images, then to constitute repertoires from the critical analysis of previous existing solutions, and to learn to deal with doubt and uncertainty, experimenting. Design is an interaction of doing and seeing, making and discovering (Schön, 1992). The experience that emerges from doing is crucial to direct design actions. The epistemological difference in teaching and learning appears to be between experimentation to confirm the pre-established on the one hand, and open experimentation of possibilities not excluded in anticipation on the other.

Uncertainty and Experimentation

Uncertainty is at the core of the creative process in design, especially in the beginning due to the lack of enough information to solve problems. Later it is reduced, for objects are clearer and there is more information to deal with them. Architects exploit several ideas in parallel and trail different routes without worrying to propose an immediate answer. Thus, uncertainty is a driving force pushing forward multiple interpretations of the same issue.

Sketches and models are witnesses of these moments and reveal the incessant search for definition and solution of a problem yet unknown. Here new structures emerge which could not be obtained just from mental images (Verstijnen**,** 1998).

Uncertainty is the primary determinant of cognitive changes (Scrivener, Ball & Tseng, 2000). When experimenting and doing something unusual, human beings learn to deal with the unexpected and increase their self-confidence to face uncertainties on more solid grounds. Theories can only be apprehended through practical application and only acquire meaning when incorporated during experimentation. To experiment is to act in order to find out what results from it (Schön, 1987). It is a unique and non-transferable learning. To learn by doing means to acquire experience (Schank, 1995).

The problem for architects is to conceive and plan what does not exist: "design is interested in how things could be" (Simon, 1996). In the science of the artificial as proposed by Simon, experimentation is permanent, for it searches for alternatives and its respective evaluations will push forward decision-taking.

In this context, since the 1960's Horst Rittel, Herbert Simon, Charles Eastman, Richard Buchanan, Nigel Cross, John Gero, Vinod Goel among others propose a set of constant and unchanging properties common to the process of design. As an ill-structured open and indeterminate problem, a design contains few definitions relative to the objects it aims at. It cannot be rationally and straightforwardly solved, for the number of variables suggests multiple choices. There is neither a definite formulation to the problem nor fixed rules for the solution. Designs end up being solved departing from previous knowledge, experimentation, trial and error and unexpected

discoveries. Due to human short term memory limitations, architects tend to break the design down into smaller parts (Simon, 1996) in a hierarchy of priorities (using their long term memories experiences as guides for new experiences - Gero & Smith, 2007). So the design is developed from the parts, in small increments towards the whole (Suwa, Purcell & Gero, 1998; Mahfuz, 1995), involving graphic registers, analysis, evaluations and new propositions (Purcell et al, 1996). Ideas do not come up at once. Rather, they are created and developed little by little due their complex nature. The consequence is unpredictable, due to circumstantial actions, alterations of parameters and personal judgment along the way, not previously fixed.

Situated acts and Convergent/Divergent Thought

When interpreting the results of their actions, architects decide on new actions affecting their environment, and their concepts change according to what they are 'seeing' (Schön & Wiggins, 1992) in their own external representations. This interaction between designer, environment and registers determines the course of action, and is called situatedness – that is, the dependency of design on the unique personal experiences of the designer.

In the creative phase of design where objects are constantly reviewed in search for different solutions (lateral transformations), the architect makes use of a *divergent thinking* (JONES, 1970). It is for no other reason that designs usually start from small simple sketches without definite forms or clear design intentions which favour the exploration of different open hypothesis without the risk of a precocious crystallization of ideas. In later definition phases on the other hand, architects make use of a *convergent thinking*, when they choose an alternative proposed before and test its adequacy and technical viability. This is after the problem has been defined and variables identified with clear objects and limits, when artefacts derive from vertical transformations, pointing to a unique and more defined solution (Rodgers, Green & Mcgrown, 2000).

Experimentation: Case Studies

The line of research the authors are engaged in is based on a collaborative problem-solving relationship between tutor and student, integrating theory and practice (thought and action) and connecting real life problems to theory with a view to both solving a problem and generating new knowledge (Coghlan and Brannick, 2002). Together, tutor and student gather information on their action and review it in order to improve or change its course. This process concentrates on the artefacts produced by the students themselves, looking beyond the register itself, which is an exercise for tutors as much as it is for students.

In Activity 4 of the course which the authors are involved in, the main evaluation criteria in order to suggest a verification of the problem finding/problem solving propensity, is first to establish the students' ability not only to define a problem clearly, but his or her capacity to critically justify it effectively as a problem in terms of the party of the design, for frequently a problem may indeed be a solution!. Also, students should be able to put clearly in words their worries, strategies, and process of investigation. The authors incorporate the suggestions by Coghlan and Brannick (2002) that the

research should be participatory and collaborative, that it is an agent for professional action change, and that the data are systematically collected and presented bearing in mind the experience of the researchers (in this case it is the beginning of a long-term road).

The authors chose 2 examples which are described below. Students were encouraged to express their ideas first in an attempt to establish a critical path. Second, they had then to justify their decisions critically by explaining making sense how those fit or not into the concept and party of their designs, step by step making use of various artefacts (thus the need to record both the intended and the unintended results). Thirdly, they were encouraged to reflect on whether they had produced new knowledge for themselves and whether it could be incorporated as repertoire to be used in new situations and new cycles of research. Even though the focus is largely on individuals' works, the results may have direct and profound consequences for the entire organization of the architectural course the authors are part of.

Student 1:

She dealt with a "School of Gastronomy" in the heart of Sao Paulo, located in a block beside the historical municipal market. She proposed a building with straight vertical volumes around an inner courtyard with one opening towards the market. Her problem was to design a cover for the yard that would be a mark of her design and creative capacity at this stage without visually interfering on the market.

She started to research on architects that proposed covers that had, in her view met the challenge in some of their designs, such as Le Corbusier, Gaudi and others, but chose the contemporaneity of Maximilliano Fuksas' New Milan Trade Fair. Combining with sketches, she started to experiment with a model in a 1:200 scale and materials such as thick (2mm) paper, Styrofoam, double-sided tape, pins and stockings, particularly seeking to define the volume of the "net" and the position of its base in relation to the use and the sensations she wanted to create in users and passers by. (Figure 1: photo 2)

She located it at the right hand side of the viewer. The result for her was an attractive and satisfying form. She first placed the footpaths of the floors of her building in front of the "net" and had an initial impression of the whole. She mentioned the fact that the sensation of something that called attention to the inside, avoiding visual conflicts to the outside, assured her of the right direction of the net, besides attracting the view as a cone pulling peoples eyes to the middle of her building, but in a "light", gradual and translucent manner, not heavy, sudden and "compulsory". Also, the right hand position of the base of the net was chosen because, as the image of her building starts to appear to the pedestrian coming from the market, it may be a little less obvious and reveals itself slower than the other side where the viewer might be immediately shocked by it. Her tests were in constant relation to her intentions in the design.

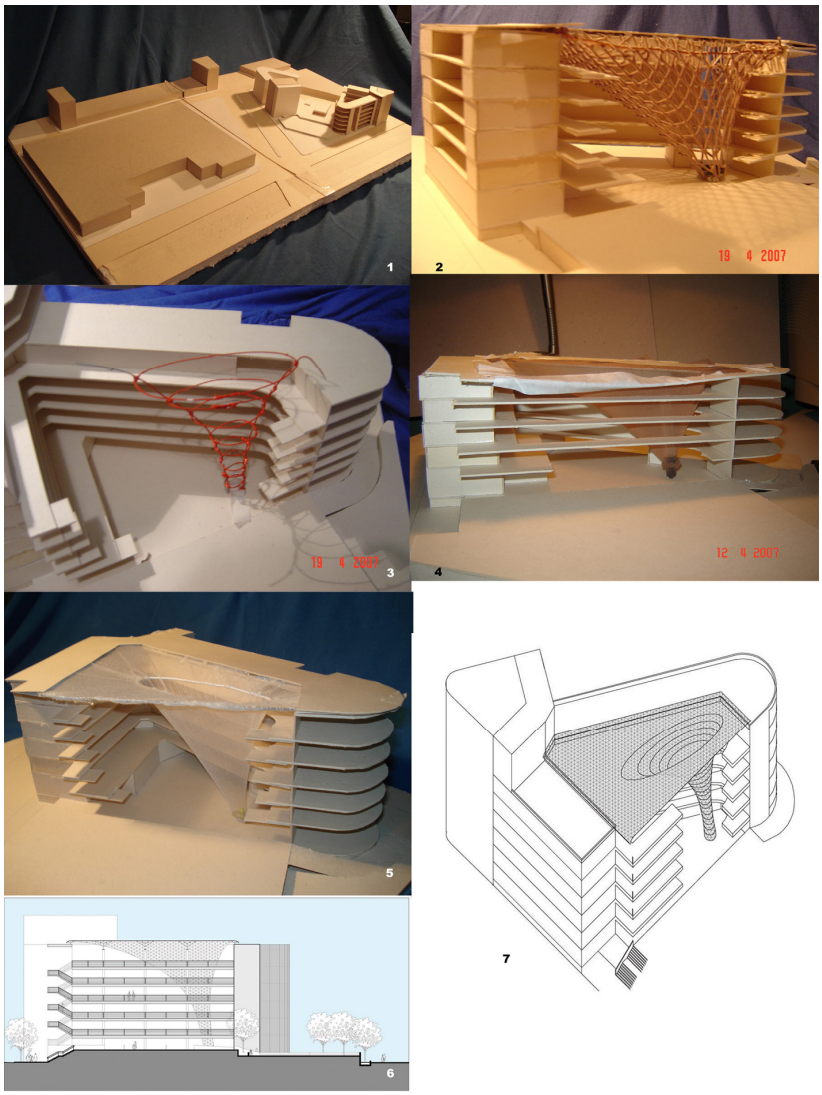

Figure 1: Student 1

After discussing strategies with the author, she photographed the first model as an elevation in order to check the various ellipses at each level of the building. She then produced a section of the net and speculated on several possibilities for the final dimensions of the ellipse. It was possible for her then to produce a proposal of a somewhat smaller net in steel wire and to notice where she would probably have to fix the sides of the net, level by level (Figure 1: photo 3). Also, it was possible for her to perceive in principle the high capacity of transferring loads and sustaining the structure that simple vertical curved elements offer.

She went on to use a stocking with larger threads and was able to develop a notion of which element would suffer greater loads by observing how each line would stretch (Figure 1: photo 4). She adopted the idea of structural ellipses which would hold the net by the transference of axial as well as compression loads. Finally, she build a model with steel wire, fast glue, sewing thread and a very fine stocking, first to check the possibility of producing a flat cover at the top or to leave it coming down in a continuous curve to the ground floor, and to examine the possibility of placing opaque boards in order to control the entrance of direct sunlight into the area below the net (Figure 1:

photo 5). She decided in the end to leave the upper ellipse flat with the top level of the building, supported by a structure coming all the way from the ground floor and fixed on the sides of the top ellipse. Also she took the decision to design opaque and medium size window frames, a structure that is supported by itself, with the loads shared by each framework element constituting it. She mentioned that light colours (the third stockings) might give a sensation of a smaller structure, which she did not expect and was not planning to test, but approved.

The result is an intriguing form, behind footpaths at the level of the floors, half open, half hidden, producing a smooth lighting result in and around the cluster in the middle of the building, and at the same time allowing for the restaurant at the ground floor to be covered, all without coming in open conflict with the market building. She considered the experience described to be directly responsible for the result. It became a methodological mark for her. In her conclusion she wrote: "(…) it was only through research and tests simulating several situations and possibilities that I was able to critically propose a solution to the problem I posed to myself". Whether the solution is acceptable in architectural terms or not, the fact seems to be that the use of experimentation with both divergent and convergent thoughts was crucial for the student to define a problem and try and solve it proposing a consistent solution.

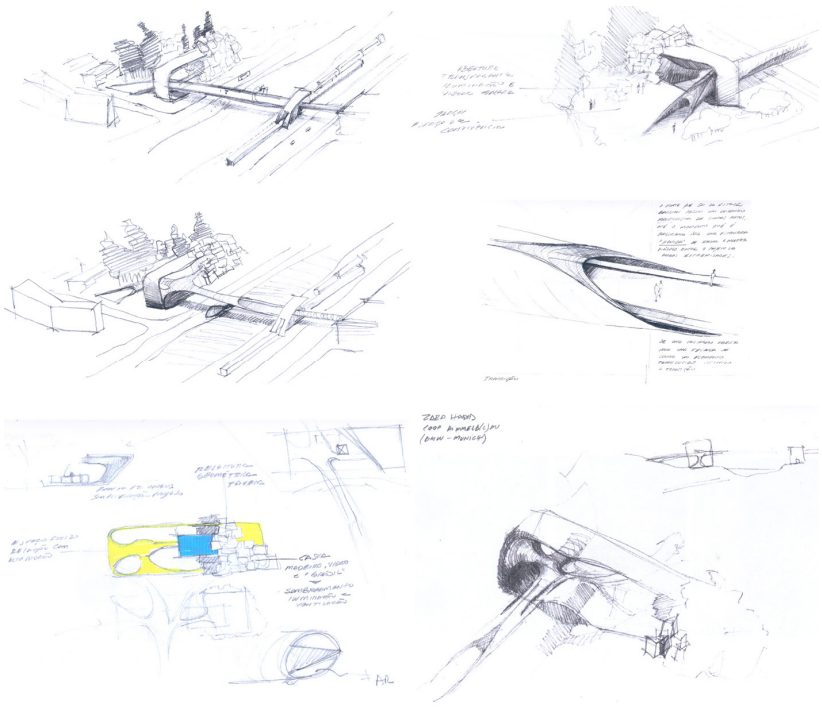

Figure 2: Student 2 – Phases 1 and 2

Student 2:

The student whished to propose a Contemporary Arts Museum in an upper class district of Sao Paulo. The area includes wealthy citizens' residences on one side and the poor on the other. It lacks adequate circulation for pedestrians, public parks or collective use equipments

The first phase of the design presents a large volume connected to an urban railway on the side of an express car artery bordering the main river of the city. On the one side the elegant and continuous forms of high standard residences and on the other the fragmented, rough cubic forms of slum dwellings. This skyline initial sketch of immediate surroundings was decisive in the design being consciously incorporated in it by the student. The subjacent concept was crucial, orienting all future decisions based on the initial premises established as a goal to be reached.

The second phase witnessed the creation of a pathway with organic forms influenced by Coop Himmelblau's BMW building. Uncertainty arose as to the technological and environmental 'blending' inadequacies of the proposal – risk of being outside of the financial scope of the design or too aggressive and disruptive visually.

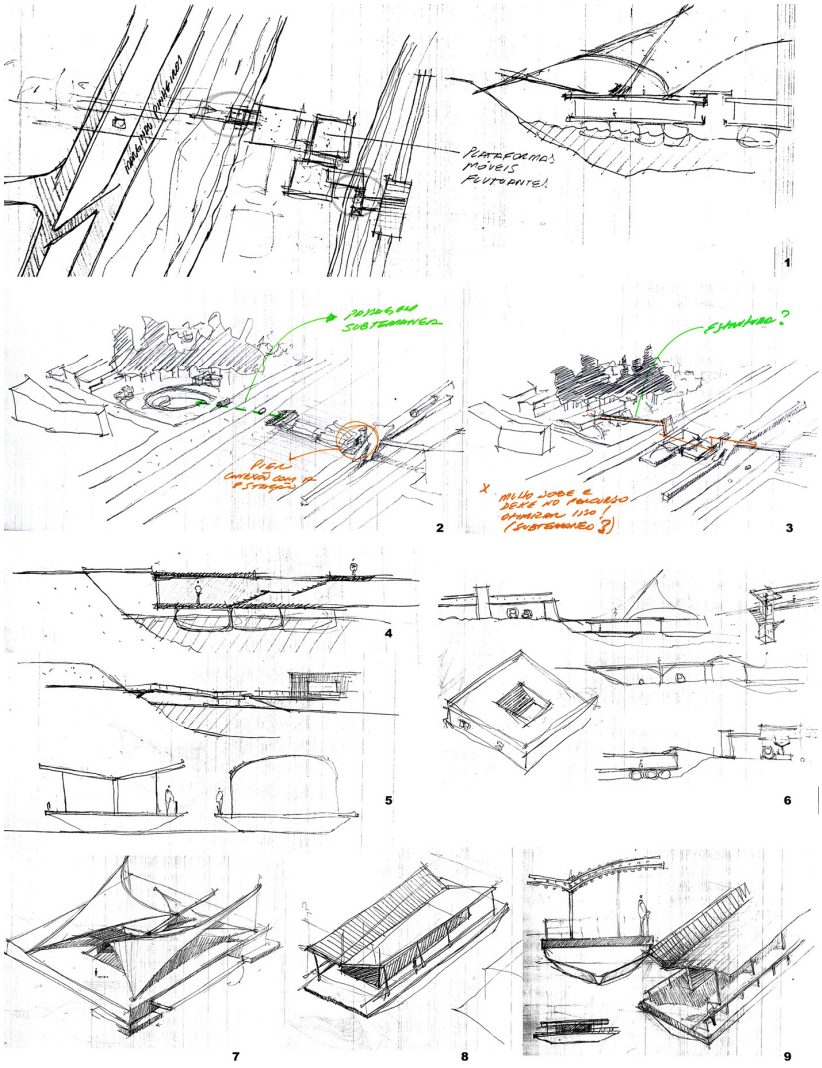

Figure 3: Student 2 – Phase 3

In the third phase the building makes use of the topography, the unevenness of the river's side. Suspended pathway gives way to floating galleries – hypothesis of crossing the river without an aggressive structure. The galleries also provided the student with the idea of itinerant devices for the museum,

which she did not considered at first. To overcome the expressway, the railway and the river became the student's main problem. Three rafts with movable connections to adapt to variable levels of the river were proposed (influenced by the Centre of Printed Arts on the River Seine in Paris and the Amazonian boats).

Divergent thinking predominates in these three phases. Lateral transformations point to varying possible solutions. Hypothesis of lower, higher and leveled to the river were raised for the rafts trying to create a structure that reflected the contrast of the area as well as served as spaces for circulation and exhibitions. Different levels of preoccupation with the building and the city are reflected in the sketches which show her strategies to deal with raised issues. It was only after several sketches that the student was able to discern the impacts of her various propositions: she saw by means of the drawings what was not yet clear.

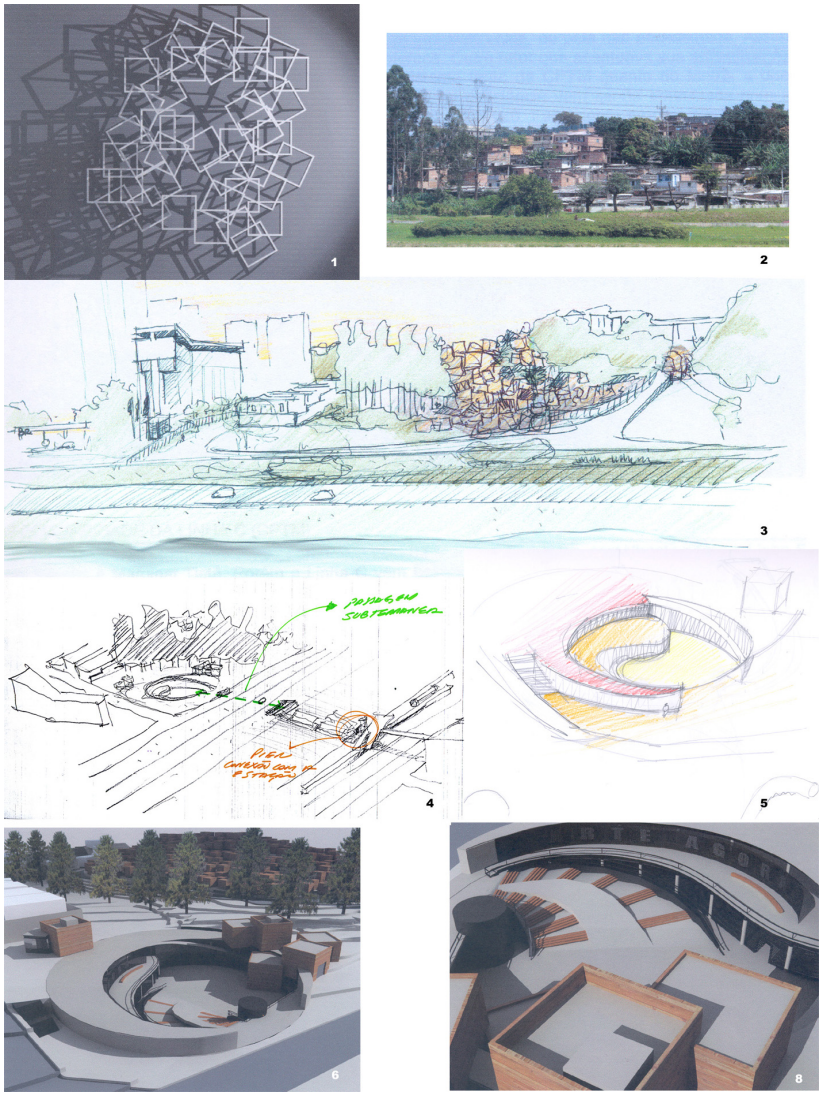

Figure 4: Student 2 – Phase 3

This last 'rafts' proposition was developed in the fourth and last phase of the design. The building becomes rather sinuous with its curves contrasting with

the cubes of the slum in a geometric re-reading, with cubic forms irregularly juxtaposing on others. The curved cover of the railway station served as inspiration for the cover of the rafts. They are connected two in two with the third free to travel the river. Here prevails convergent thinking with vertical transformations. The use of sketches in the initial conceptual phases and computer images and models in the final phase demonstrate her strategies to explore respectively creativity and development of ideas in the design without fears to admit her doubts and uncertainties in decisive moments of it. This uncertainty provoked a disquiet which motivated her towards new possibilities. Finally, the establishment of targets did not hinder her effort to create freely in the process, serving more as a general guide.

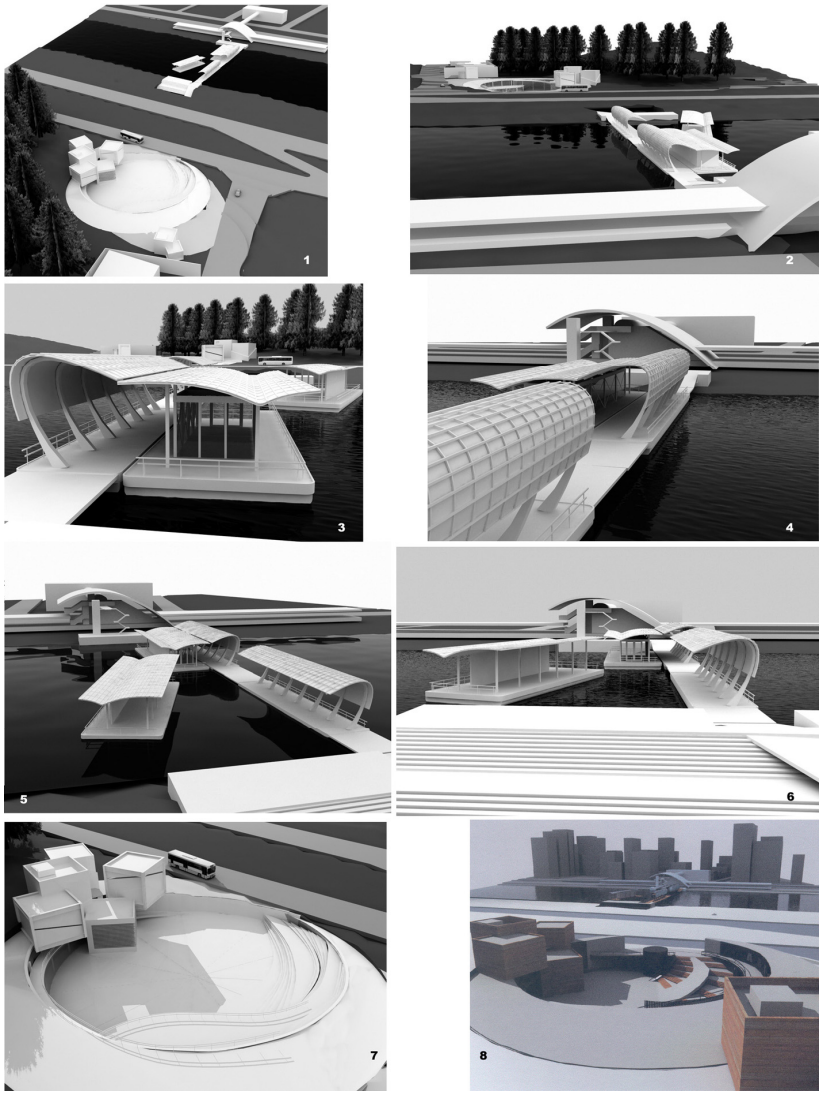

Figure 5: Student 2 – Phase 4

Final Remarks

It is still unfortunate to witness professors in the architectural environment stating categorically that any child would be able to understand that an arch is excellent to divert loads to the ground and resist uplifted, or that an untrained person would comprehend that a coil diminishes impacts – we feel that in our cars. One thing is to read or hear and another is to actually

experience and observe it working. No matter how simple the experiment is, or whether a very similar situation has been faced and solved by a third party. One is able to bear in mind the results of a direct and lived experience for years, possibly for a whole carrier, as well as to completely forget and obliterate from the mind a technical, conceptual, formal or functional situation encountered in a printed reference not frequently used. That is why this whole exercise is not focused on the solution to specific problems (although they are the objects for action), but rather on the strategies developed to deal with them.

The object of the authors is to insist and make it feasible for students during and at the end of the course to experiment and discover their own methodology for producing knowledge to deal with everyday life situations. When dealing with materials or images for instance, the idea is for them to propose not the final decision (like laminated opaque glass from Pilkington's, or red bricks), but the sensations they whish to create on the user (opaqueness, vivid colour, composition of small structural elements and so on). Only later they will be able to choose what material to fit their intentions. That is why very simple rough materials and gadgets will do in most experiments. The intent is to observe and encourage the ability to define a problem, to justify that problem, the design of their moves bearing on a particular strategy of exploration and discovery, and students' capacity to explain critically it all and to conclude making sense. The genesis of it all may be found in the sequence of artefacts produced both by the student and the professional. Apparently, the students reviewed were able to change their patterns of thinking and action that had been well established up to now. If this is really the case, then we are in business.

After all, the quality of a design derives from the student/professional capacity to realize cognitive operations combining knowledge, abilities, sensitiveness, experiences and hard work. Analysis of sketches and initial models allows for the destruction of the myth of geniality, of the innate gift, of creativity without effort cultivated by generations of architects in history. The lack of knowledge of the communicative functions of sketches, physical and virtual models produce doubt and insecurity, for they are frequently considered mere representative tools. The authors are fully aware that there is much more to be analysed and perceived in the cases of this article. Nonetheless, if the authors succeed in their intent of bringing the need for change in their educational context to light, if at a very introductory level, the whole effort will have been and continue to be worthwhile.

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